A STUDY ON CYCLONE SYSTEM ASSISTING FOR THE REVISION OF CONSTRUCTION STANDARD PRODUCTION UNIT SYSTEM

Tae-Kyung Lim[1], Han-Seong Gwak[2], Won-Sang Shin[3], Chang-Baek Son[4], Dong-Eun Lee[5]

[1] Ph.D. Candidate, School of Architecture and Civil Engineering, Kyungpook National University, Korea
[2] Graduate, School of Architecture and Civil Engineering, Kyungpook National University, Korea
[3] Graduate, Department of Architectural Engineering, Semyung University, Korea
[4] Professor, Department of Architectural Engineering, Semyung University, Korea
[5] Associate Professor, School of Architecture and Civil Engineering, Kyungpook National University, Korea
Correspond to dolee@knu.ac.kr

ABSTRACT: Construction processes are highly repetitive. A resource entity continuously cycles through work tasks that processes or uses resources. Web-CYCLONE (Halpin 1992) has been accepted as a useful tool for modeling and analyzing a specific operation. However the system has a lack of practicality as follows: (1) it does not efficiently record and keep track of operation models in a database; (2) it does not provide the functions which facilitate to retrieve corresponding model and to update local variables of the model using observed data; (3) it does not automate the complex process that executes simulation experiment, analyzes simulation outputs and generates a report on behalf of the practitioners. Therefore, practitioners have a difficulty in reusing, modifying and analyzing the existing operation models. This study introduces a Client/Server based CYCLONE that improves above-mentioned limitations in the existing Web-CYCLONE. The system was illustrated by revising CSPU in practice.

Keywords: Web-CYCLONE, Construction Standard Production Unit (CSPU), Simulation, Client/Server System

1. INTRODUCTION

1.1. Research Background and Objective

Construction projects are typically unique. However, many construction processes are repetitive (e.g., earth hauling, tunneling, road construction, and curtain-wall installation on tall buildings) and amenable to closer investigation (AbouRizk et al. 1992). After Halpin (1977) introduced CYCLONE, which is the first discrete event simulation (DES) system specialized in construction operations, many researchers developed various DES-based systems to model construction operations and to predict and improve operation productivity. Examples of these systems include UM-CYCLONE (Ioannou 1989) that allows loops to establish a cyclic network; CIPROS (Tommelein et al. 1994) that defines resource properties, design component properties, and the relationships between tasks effectively; STROBOSCOPE (Martinez 1996) that efficiently runs complex operation models; SIMPONY (AbouRizk and Mohamed 2000) that models various construction resources and their flows using icons. Such simulation systems have a capability to effectively model the repetitive processes and enables project managers to compare and evaluate the behaviors of the network model. They are considered as an effective quantitative analysis tool for the variation of a process because the effect of uncertainties on construction projects can be modeled and assessed by simulation (Martinez, 1996). Also it can simulate a construction process on the operational level by handling the random nature, resource-driven characteristics and dynamic interactions during operation. It has been proven to be an effective tool for planning and improving the performance of a construction process. There are many successful applications as follows: tunnel excavation (Touran 1987), earthmoving and heavy construction (Smith et al. 1995), bridge construction (Huang et al. 1994), pipeline construction (Shi and AbouRizk 1998), floating caisson (Halpin and Martinez 1999) and driving piles (Zayed and Halpin 2001). In spite of the various system development and successful applications in real operations, the simulation is still remained as a teaching tool in the academic environment rather than a useful management tool in practice. The construction community has not been willing to accept this tool as a definitive aid for resource optimization and productivity improvement (Halpin and Martinez 1999). The difficulties in using simulation, particularly modeling, have been widely experienced by all levels of users from academics to construction engineers (Shi 1999). The slow adoption of simulation in construction is partly due to the complexity of the construction process itself and partly due to the effort required to prepare a model using nodal representation concepts. In general, simulation tools based on process modeling (e.g., CYCLONE) require the construction practitioners to build a network model using modeling elements (e.g., queue, normal, and combined nodes in CYCLONE) (AbouRizk and Hajjar 1999). In order for construction practitioners to use a simulation tool, the methodology should be simple and graphical

(Halpin and Martinez 1999). Research endeavor has attempted to enhance construction modeling and simulation capacities as follows: DISCO (Huang et al. 1994) and COOPS(Liu and Ioannou 1992) improve CYCLONE by converting it into a computer graphic environment so that they allow users to build a simulation model by manipulating graphical symbols on a computer screen. Model reusability was studied by Halpin et al. (1990) and McChill and Bernold (1993) by developing a library consisting of standard simulation models that encompass a number of widely used construction processes. Sawhney and AbouRizk (1995) introduced a hierarchical approach for project level modeling and simulation. Shi and AbouRizk (1997) presented the resource-based modeling method to automate the modeling process for specific types of construction processes. Shi (1995) discussed the concept of a fully automated construction simulation system with the intention of simplifying the simulation process and making simulation results more accessible for decision makers.

As shown above, it is proved that construction simulation tool has been improved to facilitate the practitioners' access to it. However, limitations of the simulation still exist as follows: first, McChill and Bernold (1993) proposed a model library to remove the complex and time-consuming modeling process and to improve the reusability. However, the classification system is not established, and when reusing a model, it is also unclear how to reflect the local variables, which contributes to productivity variation, in the model. Second, practitioners and researchers have a difficulty in sharing and reusing existing models because they faces a difficulty in separating, incorporating, and updating the local variables into the existing model. Therefore, this study aims to provide strategies for improving the existing simulation system by complementing these inefficiencies.

1.2. Research Scope and Procedure

This study presents the strategies to improve the inefficient business processes that the practitioners, who are responsible for revising the construction standard production unit system (CSPU), have experienced in the process of revising the existing CSPU. The practitioners include model developers, site investigators who collect process data and evaluators who adjust the production units for this study.

The research is conducted to achieve its' objectives as follows: First, the inefficiencies that hinder the existing simulation system (i.e., CYCLONE, Halpin 1977) from being willingly adapted for construction application in practice were investigated. Then, the strategies to complement the issues were found. Second, the barriers which prevent DES from being adapted for the revision process of the CSPU in Korea were identified. Third, the functionalities required for the system extensions were elicited from the practitioners and the strategies suggested for improving the CYCLONE simulation system were found. In this way, the best strategy to use simulation tool for dealing with the issues was established. Fourth, the client/server based CYCLONE system (namely, C/S-CYCLONE) was amended by authors to accommodate the system extensions. Finally, the system performance was verified by applying the C/S-CYCLONE to the revision procedure of CSPU using case study of steel erection operation.

2. Current Revising Procedure of CSPU

Construction project consists of numerous activities and the each activity is divided into many work tasks. These tasks require various resources (e.g., laborer, equipment, material). The commitment of resources occur cost. Therefore, project participants want to computes the amount of resources required to estimate the cost for the construction (Son et al. 2010). Korean government has enacted and operated the CSPU, which defines the productivity of each trade laborers, material specifications, and construction equipments operating time for a specific operation. It has been playing a key role as a basis for estimating the construction project amount since 1970. The information reliability of CSPU has been secured by a consistent survey technique. However, the guideline manual which is used for investigating and analyzing the CSPU provides only basic regulations. That is why the site investigators perform a measurement in their own ways for an observation on construction operation. So that it results in a lack of representation and reliability of the CSPU. For example, the amount of work, task duration, and the number of laborers are an important basic data attributes that are essential to generate a production unit on a targeted operation. Nevertheless, the manual defines only the regulation that site observation should be conducted during whole period from a work preparation to cleanup excepting lunch time. it does not provide how to measure the operation time (Son et al. 2010).

The existing revision process of CSPU has the procedural issues as follows; first, the targets that site investigators have to measure are not strictly defined. Second, the loss of measured data and additional manpower consumption are concerned, because the job-site data collection takes place right after being recorded by hands in a daily report.

3. CLIENT/SEVER BASED CYCLONE

To facilitate the practitioners who have no expertise on simulation modeling and analysis to implement a simulation experiment, three strategies are identified as follows;

3.1. Improving Reusability of Construction Operation Models

The CSPU in Korea (Construction Research Institute in Korea, 2008) is classified into 20 major construction trades to cover all construction activities. An individual construction trade (or activity) is subdivided into operations. The revision of CSPU takes place typically at the lowest hierarchy of its classification system. Therefore, the practicality of simulation tool may be improved when a simulation model is developed in the lowest hierarchy. The CSPU manual provides a classification system for major activities in a construction project. In addition, it provides information involved in resource type, its measurement unit, amount of resource input for a standard work task, and which tasks should be included or not in an operation. Model developers should identify cyclic resource processes in an operation under study by using CSPU manual and site investigation. Then, he/she establishes an operation model by considering the sequential relationship between these resources processes. The operation model developed in the way is recorded in the form of operation templates which can be retrieved and reused by practitioners. The operation template defines the resources and the tasks involved in the operation. Figure 1 shows the modeling environment of CYCLONE that facilitates model developers to make an operation modeling at a client tier.

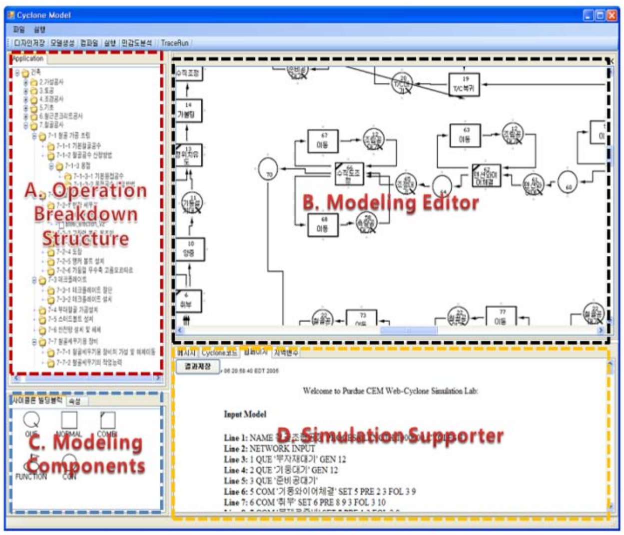

Figure 1. CYCLONE-Modeler for developer

3.2. Updating Operation Template with Local variable

The operation template retrieved by a site investigator provides the information relative to resources status (e.g., the type and number of skilled workers and assistant worker, the type and number of equipment and material), tasks involved in individual resources), sequential relationship among the resource processes, and the time required to accomplish each task. To estimate accurately the productivity of resources relative to the operation by reusing an operation template, the template should be updated using observed data involved in local variables. This study considers "crew configuration", "working time" and "amount of work" as common local variables. Therefore, the modules added in the existing CYCLONE system require for classifying and identifying intelligently which components belong to which resource or task in the selected operation template and for manipulating attributes depending on resource or task components (e.g., Queue, Normal and Combi), respectively. The modules facilitate for practitioners to measure and record productivity data involved in resources and working times as fundamental information for the revision of CSPU in a uniform fashion. A site investigator can accesses to the CYCLONE-Modeler, which is called Operation Navigator, by using smart-phone as shown in Fig.2. It provides mobile customized user interfaces that enable to retrieve and reuse an operation template for review and to collect data relative to resources and their working times.

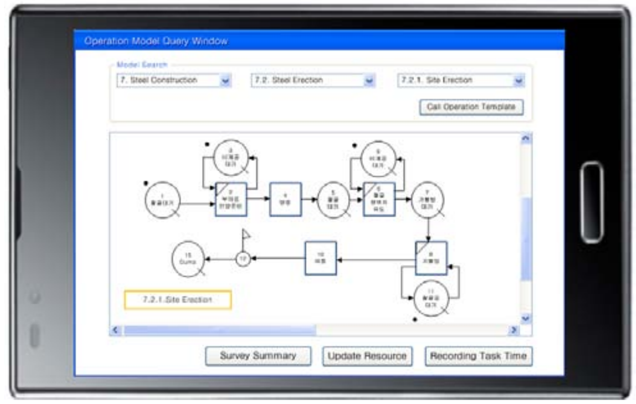

Figure 2. Operation Navigator for site investigator

3.3. Executing Intelligent Server for Simulation

The intelligent server (IS) executes simulation experiment, analyzes simulation outputs, and generates a report for revising CSPU on behalf of the practitioners. It performs a series of processes as follows. First, it updates an operation template under study using observed data. In detail, IS explores an operation template that corresponds to a desired operation ID and then update the local variables with data obtained from job-sites. It is noteworthy that the attributes such as for primary tasks' times (e.g., normal and combi components) in an operation template are defined in a probability distribution function (i.e., pdf) to generate random numbers during simulation experiment. An algorithm (named as SearchPDF) which estimates a best fit probability distribution function and its parameters from historical data is developed and embedded as one of the intelligent estimating module in the system. The SearchPDF algorithm automatically estimates a best-fit-pdf and corresponding parameters and then assigns estimated pdf into attributes relative to tasks.

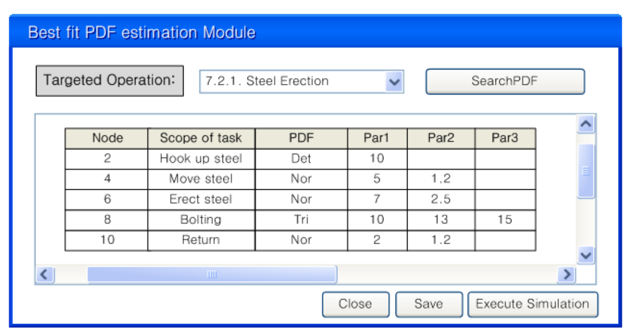

Figure 3. Module for estimating Best-fit-PDFs from working time data

Second, the system executes simulation experiment by using the updated operation template obtained from the previous step. It should be noted that the operation template still is a graphic model. Therefore, the model must be converted into text based model which allows Web-CYCLONE engine to execute simulation experiment. IS equips with intelligent translator that converts a graphical model into a text model (i.e., operation source) in accordance with the CYCLONE syntax. Then, the system sends the source code to the Web-CYCLONE. It should be noted that the C/S-CYCLONE system integrates a legacy system of Web-CYCLONE to ease the development. In this way, the researcher could expedite developing additional function modules in response to the practical requirements.

Third, the IS calculates representative production units of the operation under study. The production unit (e.g., man/ton) refers to the amount of resource (e.g., 1man, 1ea) required to perform a unit work (e.g., 1ton, 1m2, 1m3 etc) and its reciprocal implies a concept of productivity (e.g., ton/man). The system retrieves the simulation outputs from Web-CYCLONE engine and stores them into the system database in the server.

The result data requires for the revision of steel erection operation consist of the type and number of laborers as shown in Fig4. The sets of total working times for each task and the amount of steel material are shown. The production unit is calculated using Eq.1.

$$Prod.Unit = \frac{Crew \times Member(\mathrm{man/crew})}{Amount\ constructed(unit)} \times \frac{Working\ time(hr)}{8hr\ /\ day} \quad \text{...Eq. 1}$$

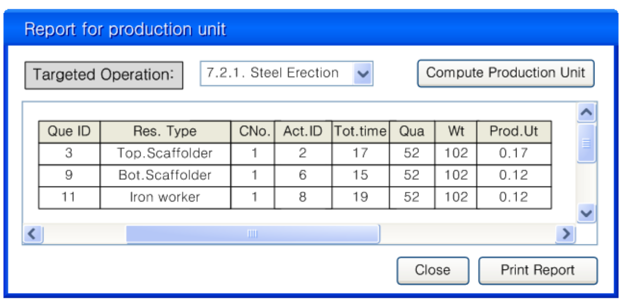

Figure 4. Module for calculating production units

4. CONCLUSION

This paper presents the C/S-CYCLONE system that extends the existing CYCLONE simulation system. It is specialized for the practitioners to be engaged in the revision process of CSPU in Korea and to encourage employing simulation into its revising. To take advantage of using simulation technique in practice, this study suggests three strategies as follows: (1) improving reusability of construction operation models, (2) updating operation template by incorporating local variables, and (3) executing intelligent server for simulation. This research may contributes to improve the accessibility and usability of simulation tool in practice because it presents strategies and modules to automate the process of simulation modeling and execution, and complement existing simulation system by accommodating the practitioners difficulties in practices.

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